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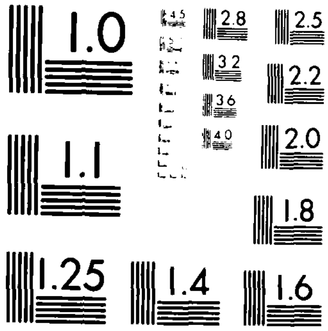

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THE DETERMINATION OF DRAG OF A CIRCULATION CONTROL AIRFOIL TESTED IN THE 7- BY 10-FOOT TRANSONIC WIND TUNNEL

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

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Tsze C. Tai

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ABSTRACT

A special procedure for using the Jones method for determining the profile drag in highly disturbed wake behind a circulation control airfoil is proposed. The procedure suggests that the value of the freestream dynamic pressure be adjusted so that the baseline of the integrand in the Jones method coincides with the zero reference line. Excellent agreement was observed between the results of the new procedure and those of the simultaneous solution values of the Jones and the Squire-Young methods.

INTRODUCTION

The drag of a two-dimensional airfoil in a wind tunnel usually can be determined in three ways; namely, (a) integration of the surface pressure force in the free-stream direction along with the skin friction, (b) integration of the momentum deficiency in the wake sufficiently far downstream of the airfoil, and (c) direct force measurement. Approach (a) has been found to yield serious inaccuracies[1,2,3] which far exceed theoretical expectations. Approach (c), on the other hand, is relatively inconvenient to implement. The momentum deficiency method, Approach (b) therefore, often has been employed by experimental aerodynamicists because of its simplicity and reliability.

The approach involves the measurements of traversing pitot ~~pitots and~~ static tubes across the wake of the airfoil. The experimental data can then be deduced either by the method of Betz or that of Jones[4] These methods offer reasonable accuracy in conventional airfoils at small to moderate angles of attack. For airfoils at high angles of attack or bluff bodies where the fluctuations of the downstream flow are caused by the shedding of vortices, either method lends to erroneous results.[5] Other critical comments on these methods are given by Taylor.[6]

In testing the circulation control airfoil in a wind tunnel,* the determination of drag presents a problem that has not been considered previously. As opposed to the conventional airfoil, a typical circulation control airfoil is equipped with a blowing slot on the upper surface for energizing the flow in the viscous layer and a rounded trailing edge for deflecting the jet. The presence of the blowing jet and its influence on the downstream wake pattern require careful treatment in applying the usual traverse method.

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*During 1977 to 1980, the circulation control airfoils have been applied to an A-6 testbed aircraft, an H-2 helicopter, and a stopped rotor (X-Wing) aircraft at DTNSRDC.

In the present paper, special consideration has been given in using the Jones method for the determination of drag of a circulation control airfoil tested in a transonic wind tunnel. To assure the drag values obtained by the new procedure, a modified Squire-Young formula has been employed and operated with the same wake dat for the Jones method.

WAKE SURVEY DATA

A circulation control airfoil model, which is a 16-percent thick, cambered ellipse with a tangential blowing slot near the blunt trailing edge, was tested in the 7- by 10-ft transonic wind tunnel at the David Taylor Naval Ship Research and Development Center. The model, designated 103, has a rectangular planform with an 18-in. (45.7-cm) chord and a 10-ft (3.05-m) span. The test arrangement is depicted in Figure 1. To measure the drag of the model, a wake survey mechanism consisting of five pitot-static tubes is mounted about one-chord length downstream of the airfoil. The wake flow was then measured by moving the mechanism vertically, as schematically shown in Figure 2. The measurements include the total pressure survey and the static pressure survey. Although the tunnel has a height of 84 in. (24.2-cm), the survey mechanism travels only inside a range of -15 to 18 in. (-38.1 to 45.7 cm). Outside this range, the variation of the flow was considered minimal, and its contribution to the drag value would be negigible. A typical wake survey (Run 216) is listed in Table 1. The variation of the measured total pressures and static pressures across the wake is shown in Figure 3.

DETERMINATION OF DRAG

JONES METHOD

The drag coefficient given by the Jones method is

$$C_{D_J} = \frac{2}{c} \int_{wake} \sqrt{\frac{g_2 - p_2}{q_\infty}} \left(1 - \sqrt{\frac{g_2 - p_\infty}{q_\infty}} \right) dy \qquad (1)$$

where g is the total pressure and p and q have their usual meaning. Suffix ∞ represents flow properties of an undisturbed stream far downstream and suffix 2 denotes those at the measuring station.

The basic advantage of using the Jones method is that it allows the wake measurement to be performed at a short distance behind the body. As the form appears, the C_D value not only depends on the direct measurements of g_2 and p_2, but

also is very sensitive to the freestream quantities p_∞ and q_∞. A small inaccuracy in the freestream dynamic pressure measurement may result in a large discrepancy in drag values. As indicated in Figure 4, for a given set of g_2 and p_2, and a fixed p_∞, a 1-percent variation in q_∞ (that is, q_∞ = 127 lb/ft^2 ±1 percent) yields ±30 percent variation in C_D. A 2.5-percent error in q_∞ may double the drag coefficient.

The heavy dependency on the q_∞ quantity makes the precise determination of the q_∞ value a necessity. Generally the downstream flow pattern may alter the upstream condition due to the propagation of the downstream disturbance through a subcritical stream in a transonic or subsonic test. The feedback may become noticeable (that is, a 1- to 2-percent variation in q_∞ is possible) in the case of a circulation control airfoil where the downstream flow is substantially affected by the blowing jet.

The situation for such a critical requirement is significantly eased by graphically analyzing the integrand, F, of the Jones method:

$$F = 2\sqrt{\frac{g_2 - p_2}{q_\infty}}\left(1 - \sqrt{\frac{g_2 - p_\infty}{q_\infty}}\right) \qquad (2)$$

A series of plots of F quantity across the wake survey station are shown in Figure 5 using q_∞ as the variable (Run 216, M_∞ = 0.3, α = -0.01 and $C\mu$ = 0.022, with p_∞ = 2002.95 lb/ft^2). Keeping everything fixed, a subsequent increase in q_∞ value moves the wiggling baseline of the F pyramid upward, as indicated in Figure 5. Somewhere near q_∞ = 126 lb/ft^2, the F baseline coincides with the reference (zero) line. There the fluctuation of F contributes nothing to the C_D value. It is therefore postulated that q_∞ takes on the value that satisfies the condition

$$\int_{y_{lower}}^{y_a} F\,dy + \int_{y_b}^{y_{upper}} F\,dy = 0$$

The determination of y_a and y_b is arbitrary, however. It may be guided by experience and observation so that the resulting C_D will be fairly independent of the arbitrariness. It is of interest to note that the distribution of F outside the main wake region is fairly equal for both the upper and lower sides, unlike those of p_2 and V_2; see Figures 3 and 6.

MODIFIED SQUIRE-YOUNG METHOD

This method has been popularly used for calculating the profile drag from theoretical boundary layer considerations.[7] Two versions were formulated, one with pressure gradient and the other without it. The method was modified by Young[8] to account for the compressibility. Although the method was developed primarily for theoretical calculations, it can also be used to determine the profile drag from wake surveys.[9] Application of the method to given wake flows can be found elsewhere.[1,10]

The modified Squire-Young method allowing for variation of the static pressure across the wake can be written in the form

$$C_{D_{SY}} = 2\,\frac{\bar{\theta}}{c}\,\frac{\rho_e}{\rho_\infty}\left(\frac{u_e}{V_\infty}\right)^{\frac{\bar{H} + H_\infty + 1}{2}} \tag{4}$$

where

$$\bar{\theta} = \int_{wake} \frac{\rho u}{\rho_e u_e}\left(1 - \frac{u}{u_e}\right) dy - \int_{wake} \frac{p - p_e}{\rho_e u_e^2}\, dy$$

$$H = \frac{\delta^*}{\bar{\theta}}$$

$$\delta^* = \int_{wake}\left(1 - \frac{\rho u}{\rho_e u_e}\right) dy \tag{5}$$

$$H_\infty = 1 + (\gamma - 1)\, M_\infty^2$$

In the case of a wake flow, the quantities ρ_e and u_e should be determined at the edge of the wake.

Using the same wake survey data of Run 216 (Table 1), the velocity profile is depicted in Figure 6. Taking the edge properties by the mean value of the first 30 points of the upper side, the results of C_D versus q_∞ were plotted in Figure 7. The figure indicates that the drag coefficients calculated by the modified Squire-Young method are fairly insensitive to the variation of the freestream velocity. As opposed to the Jones method, the drag coefficient decreases as q_∞ increases. The range of the drag coefficients calculated by the modified Squire-Young method is about the same as that found by the Jones method.

SIMULTANEOUS SOLUTION

The opposite trend of the drag coefficients calculated by the two preceding approaches offers an excellent opportunity to determine the value of q_α uniquely by intersecting the two C_D curves based on the same set of raw data; see Figure 8. A q_α = 126.07 from both methods can be found that yields the same C_D value (C_D = 0.0424). For q_α = 126.07, the integrand F of the Jones method is shown in Figure 9, where the simultaneous solution is surprisingly close to the newly proposed technique for adequately using the Jones method. The figure also shed some light regarding the selection of y_a and y_b values for Equation (3). It was found that:

$$y_a = -0.5$$
$$y_b = 0.5$$

satisfy Equation (3). The nature of empiricisms for selecting y_a and y_b has not been removed, however. Further, close to the disturbed center, y_a = -0.043 and [illegible] 0.48 will also satisfy Equation (3). By the same token, one finds that [illegible] pairs of y_a and y_b values exist when they move away from the disturbed [illegible] (i.e., toward y_{upper} and y_{lower}). As a rule of thumb, the pair (-0.5, 0.5) [illegible] to be the best choice. Inasmuch as the wiggling F baseline is close enough [illegible] zero reference line, the C_D result should be virtually independent of the [illegible]

DISCUSSION OF RESULTS

[illegible] drag coefficients for the circulation control airfoil (Model 103 [illegible] -0.01 for a series of blowing coefficient C_μ values (Runs 212 [illegible]) are summarized in Table 2. Also, an additional case of M_α = 0.5, [illegible] = [illegible], and C_μ = 0 (Run 34) was considered. For each case, the methods of Jones and [illegible] Squire-Young were applied for three consecutive q_α values, with all other [illegible] fixed. Results of the simultaneous solution based on the two approaches were then obtained.

[illegible] all seven cases considered, the simultaneous solution consistently deter- [illegible] q_α value that brings the baseline of the integrand F to coincide with [illegible] zero reference line. Figure 9b shows the graphical display of such a coinci[illegible] [illegible] proposed special procedure for the Jones method seems to be fully supp[illegible] by the modified Squire-Young analysis.

Figure 10 shows a second-order least square fit for the simultaneous solution results. Also plotted in Figure 10 are the results obtained by a preliminary data reduction program and by an earlier version of the new procedure for the Jones method. The former are labeled "Preliminary," and the latter, designated as "Earlier Version," have been reported in Reference 2. The "Earlier Version" data were formed independently by inspecting only the F baseline behavior and were never checked by any other data reduction schemes, including the Squire-Young method. It appears that the agreement between the "Earlier Version" data and the simultaneous solution values is reasonably well within the allowable experimental fluctuations. The "Preliminary" data, on the other hand, are generally 20 to 30 percent lower than the values obtained by the new procedure.

To see how the integration of the surface pressure (the so-called pressure drag) compares with the profile drag, Figure 11 is presented. Again, Run 216 is used for illustration. The integrated pressure drag coefficient was found to be $C_{D_p} = 0.1185$, based on the measured surface pressures listed in Table 3. If the equation, that the total drag is the sum of the pressure drag and skin friction, less the blowing momentum coefficient[2] holds, a sizable negative frictional drag could result, which is physically impossible. Therefore, the idea of using the pressure drag shoud be discarded.

CONCLUDING REMARKS

The present work has allowed the following conclusions:

1. The Jones method is very sensitive to the fluctuation of the freestream dynamic pressure. To remedy the problem, a procedure that forces the mean of the integrand to vanish outside the disturbed region is proposed which seems to yield the correct drag values.

2. The simultaneous solution of the Jones and the modified Squire-Young methods seems to offer a reliable profile drag coefficient from the wake survey data.

3. The integration of airfoil surface pressure in the freestream direction may lead to erroneous drag values.

ACKNOWLEDGMENTS

The present work was supported by the Independent Research Program at the David Taylor Naval Ship Research and Development Center under Work Unit 1606-105. The author is indebted to S. de los Santos and R.M. Williams for their enlightening discussions. Thanks are also due to J.B. Wilkerson, J.S. Abramson, and S.M. Gottlieb for providing the wind tunnel data.

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Figure [illegible] - The Circulation Control Aircraft Model Installed in the 7- by 10-Foot Transonic Wind Tunnel

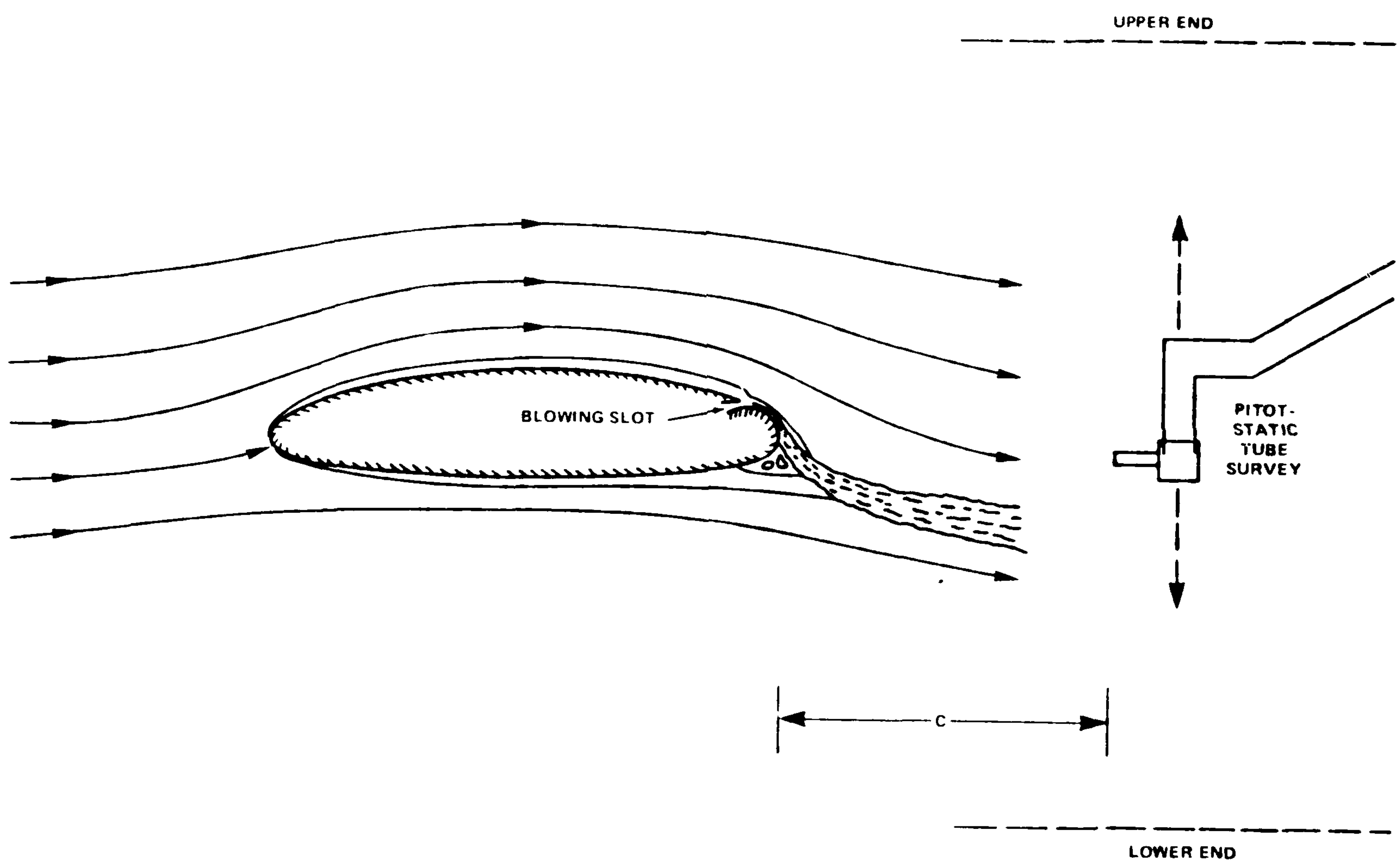


Fig. 2 - Schematic of the Wake Survey

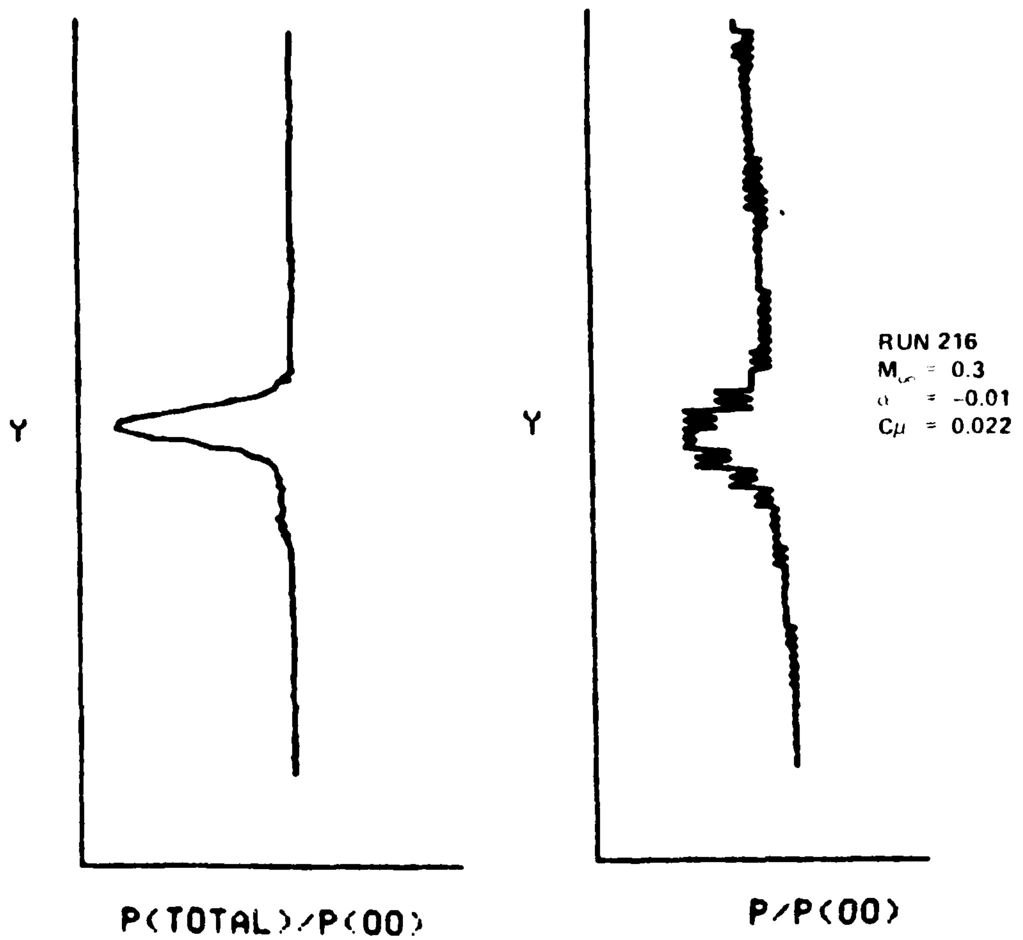


Fig. 3 - Total and Static Pressure Profiles Measured in the Wake of a Circulation Control Airfoil

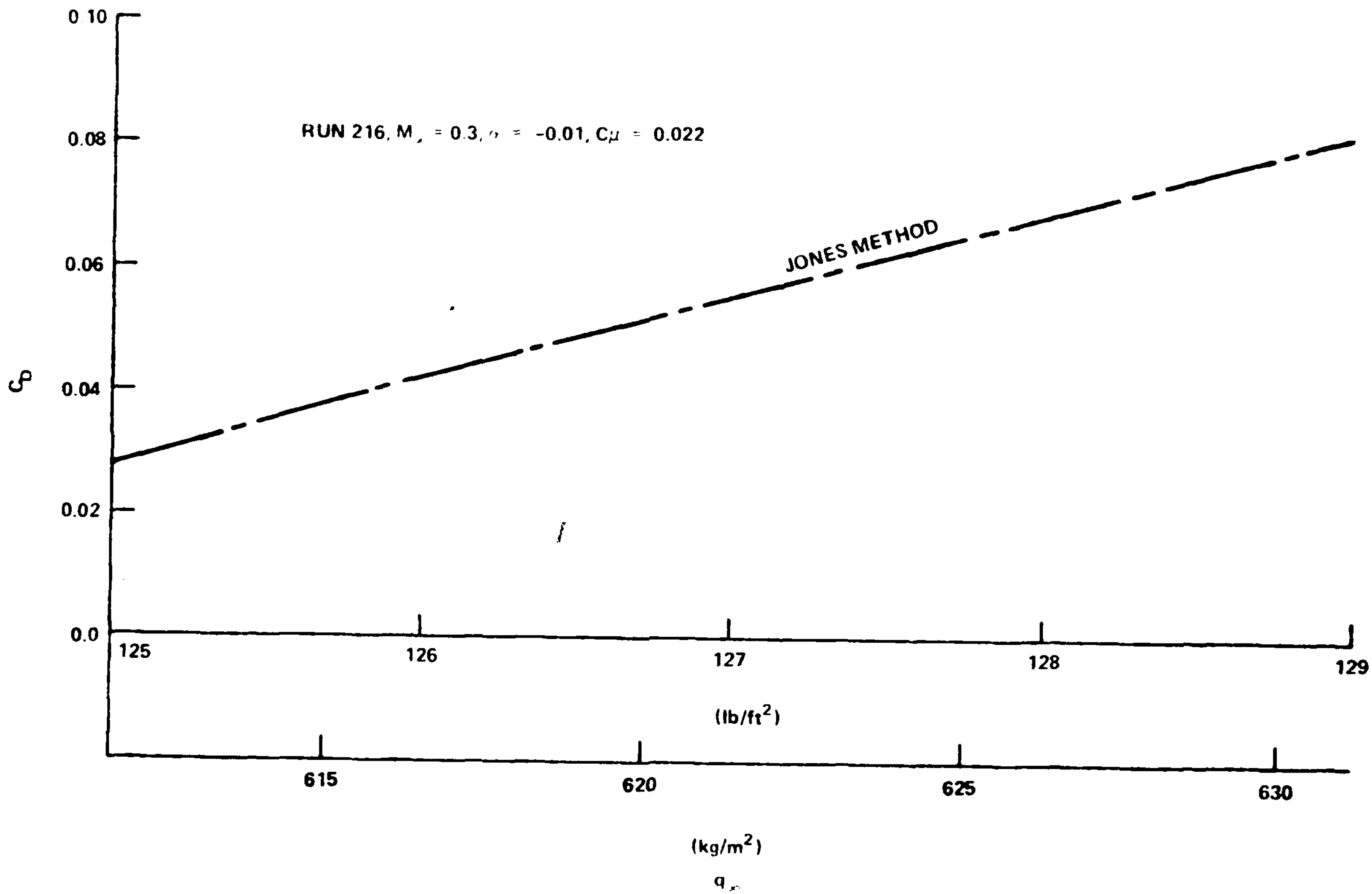


Fig. 4 - Effect of Freestream Dynamic Pressure Variation on Drag Coefficient Using the Jones Method

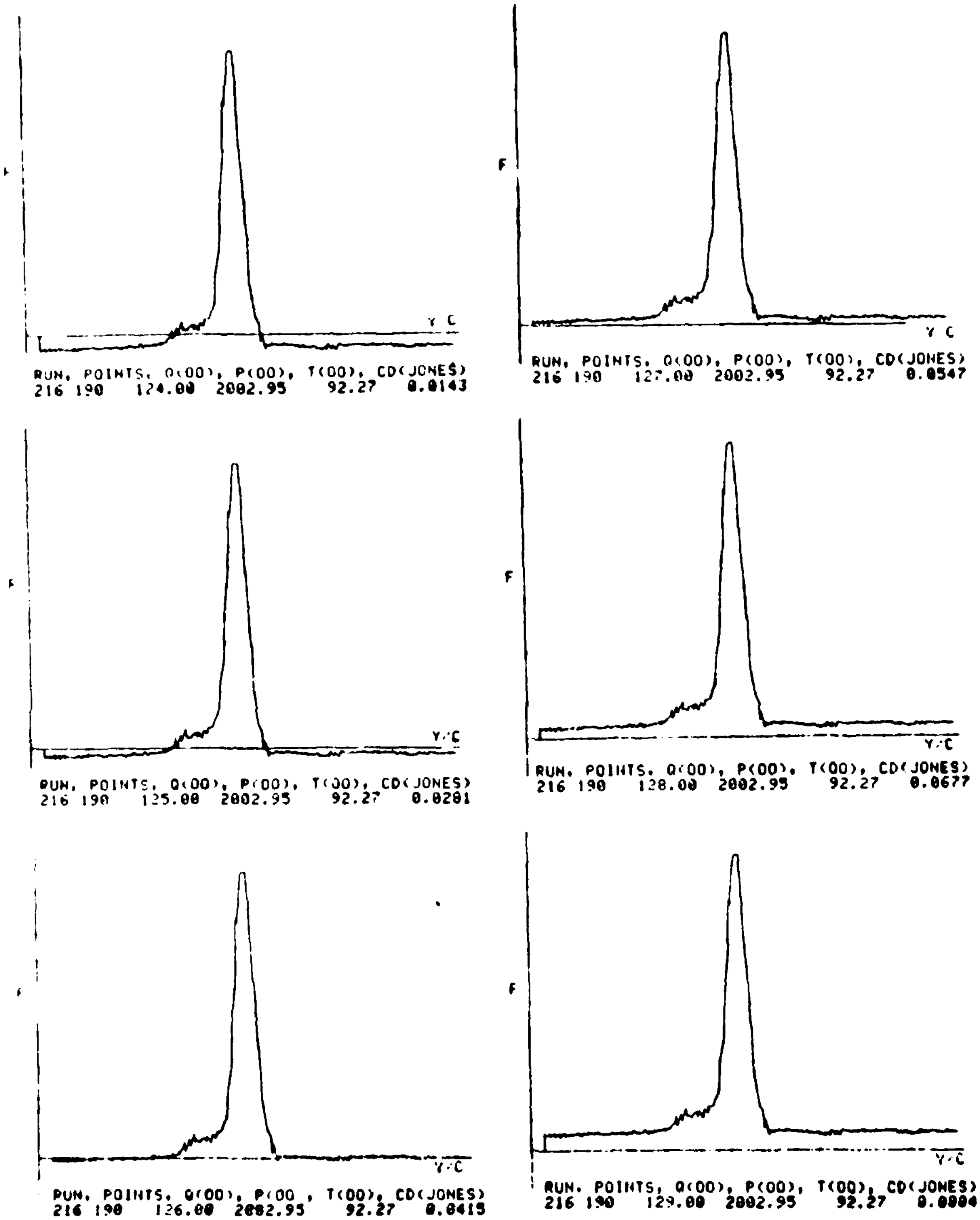
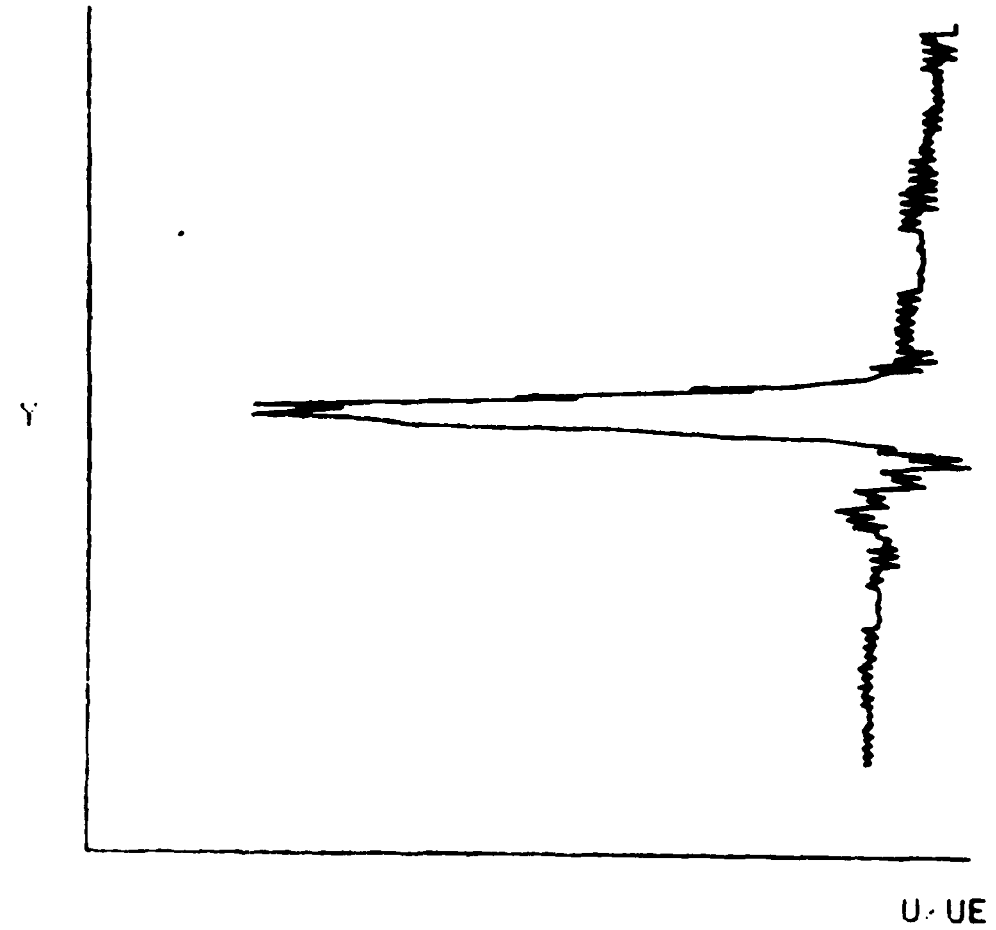


Fig. 5 - Effect of Freestream Dynamic Pressure on the Integrand of the Jones Method

UMIN, UMAX
0.75, 1.01
RUN, Q(OO),P(OO),T(OO),U(OO), UE, H, THETA, CD(SQUIRE-YOUNG)
216 126.07 2002.95 92.27 345.29 346.38 1.5608 0.3780 0.0424



Profile of a Circulation Control Airfoil at

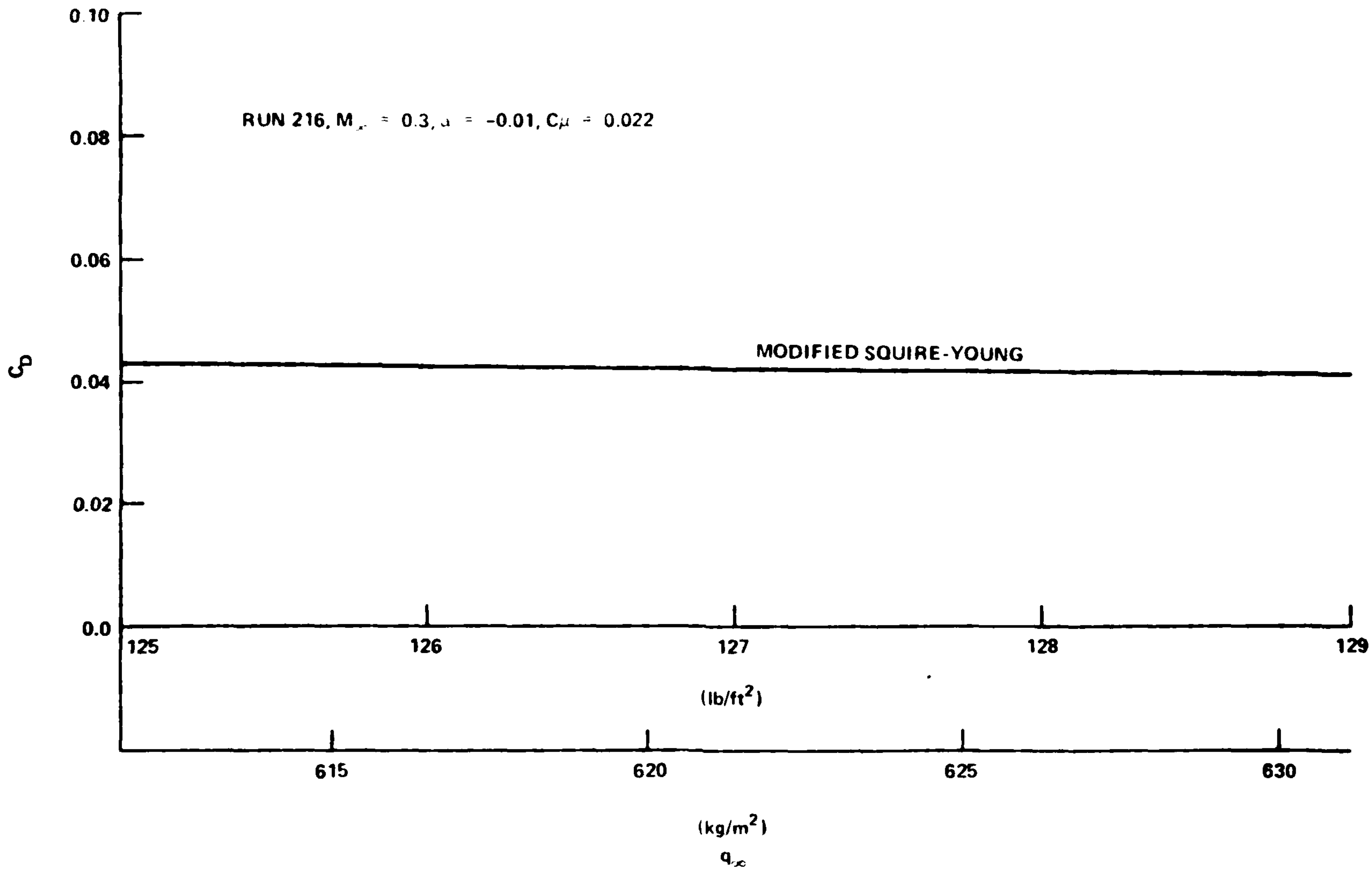


Fig. 7 - Effect of Freestream Dynamic Pressure Variation on Drag Coefficient Using the Modified Squire-Young Method

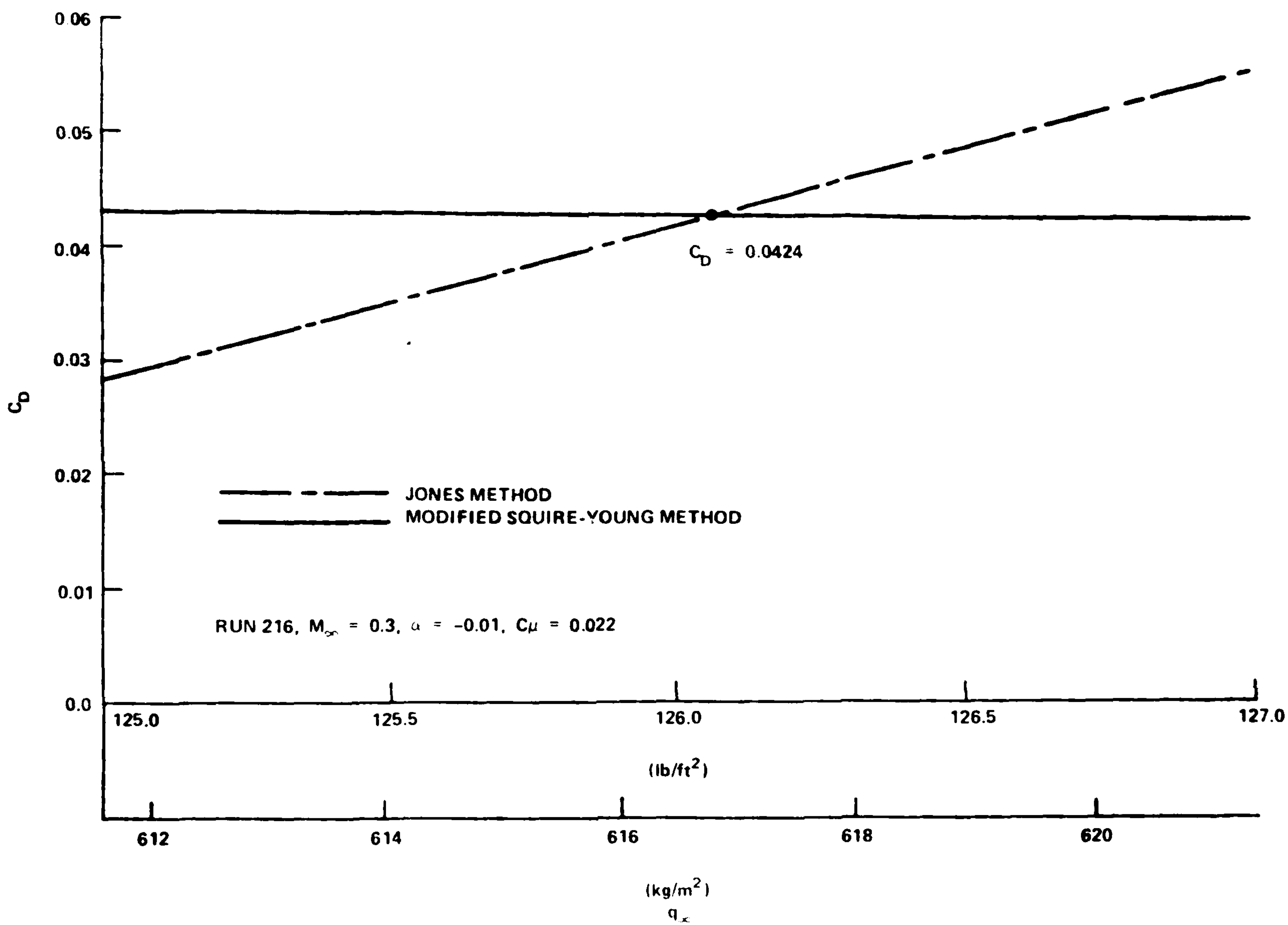


Fig. 8 - Simultaneous Solution of the Jones Method and the Modified Squire-Young Method

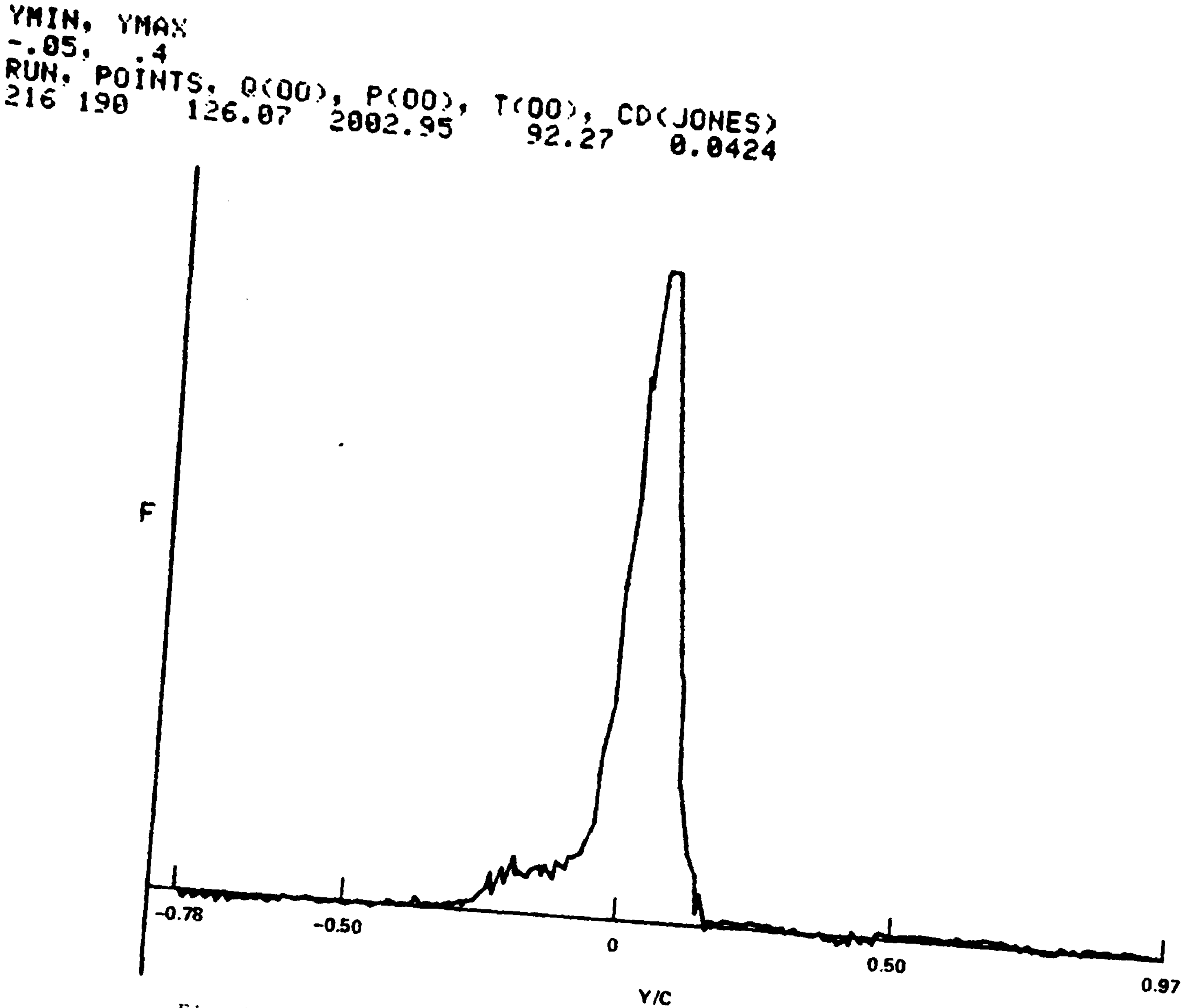


Fig. 9 - The Distribution of Integrand in the Jones Method with q_o Obtained by Simultaneous Solution

Fig. 9a - Run 216

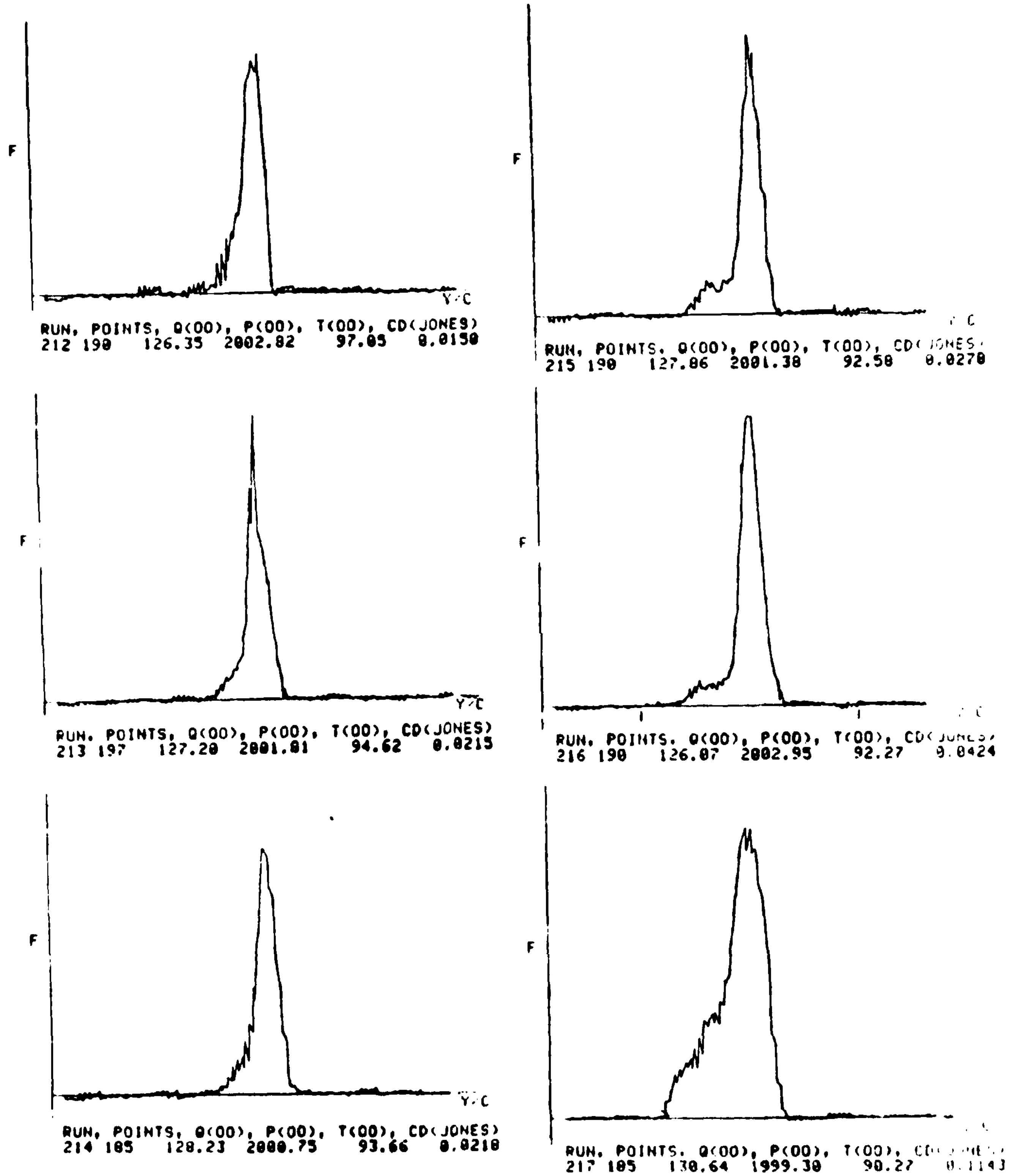


Fig. 9b — Runs 212 through 217

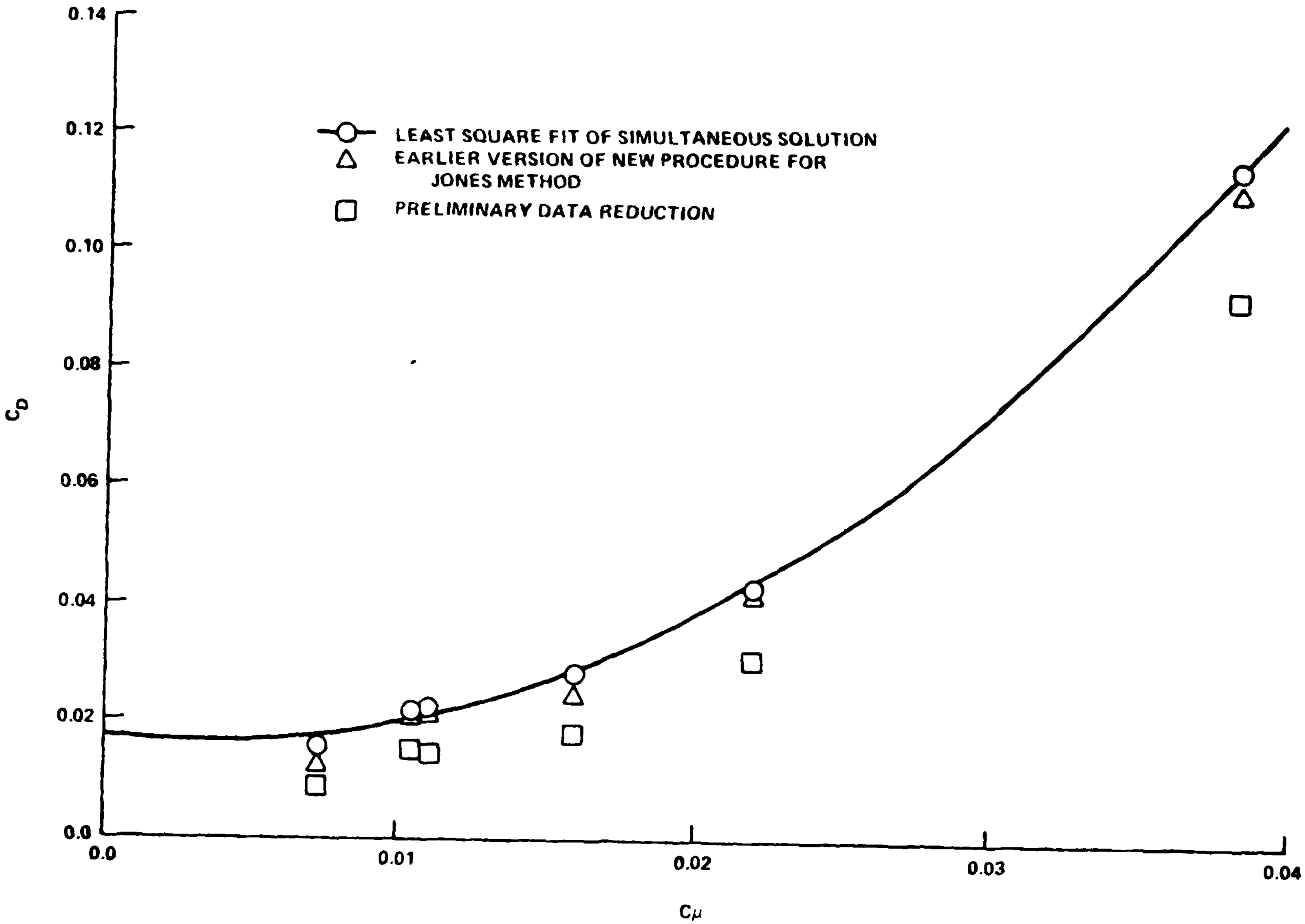
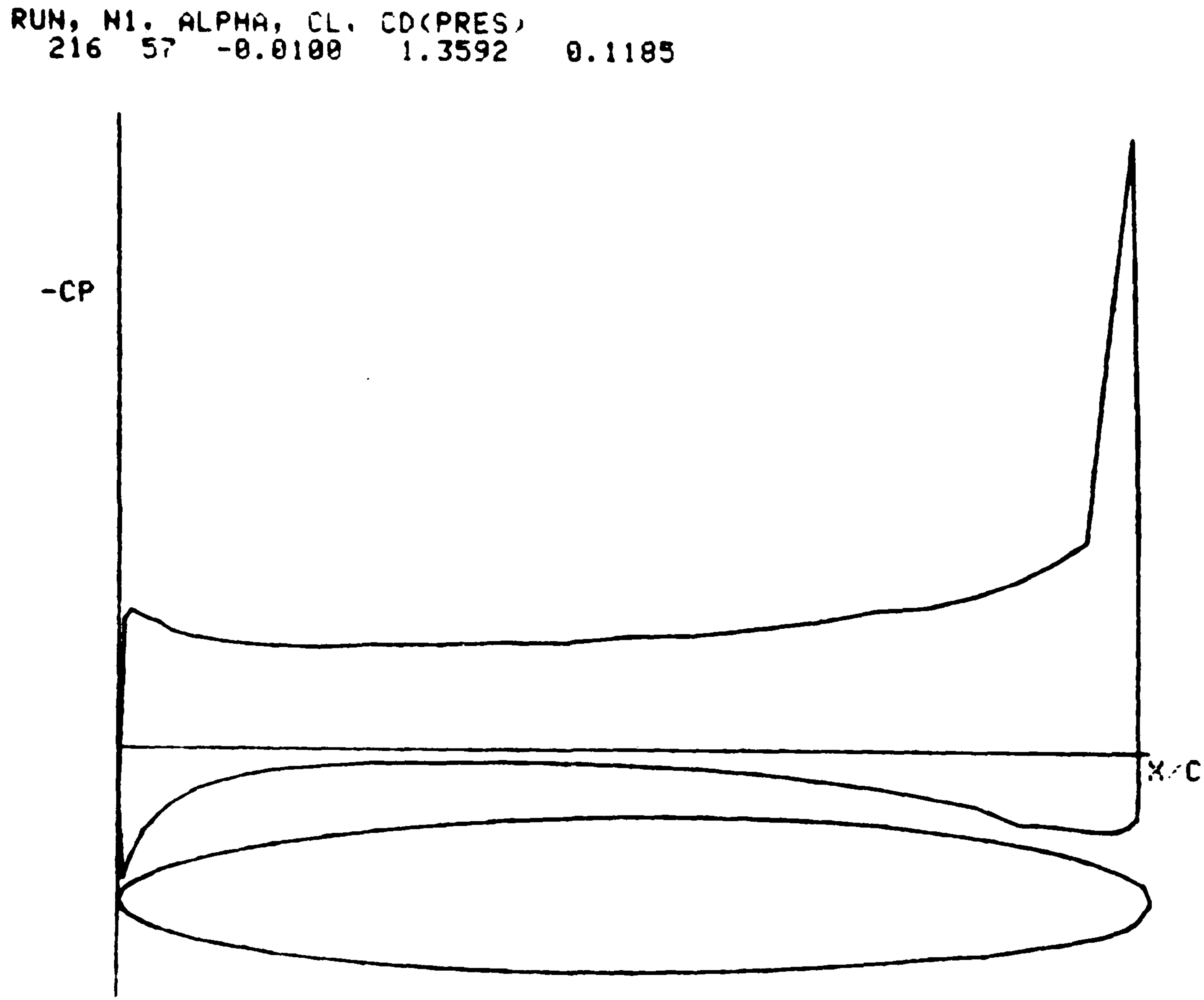


Fig. 10 - Drag Coefficients Determined by Three Different Methods
(Model 103, Runs 212 through 217)



[illegible] tribution [illegible] a Circulation [illegible]
[illegible] -0.0[illegible] and C_{μ} = 0.02[illegible] [illegible]

TABLE 1 - WAKE SURVEY DATA, RUN 216

N	Y(in)	B_2 (lb/ft^2)	P_2 (lb/ft^2)	N	Y(in)	B_2 (lb/ft^2)	P_2 (lb/ft^2)	N	Y(in)	B_2 (lb/ft^2)	P_2 (lb/ft^2)
1	17.467	2129.93	2000.67	67	6.192	2129.08	2003.27	133	-4.601	2126.76	2004.77
2	17.032	2129.93	2000.67	68	6.101	2129.10	2003.45	134	-4.690	2128.42	2006.47
3	17.023	2129.87	2003.04	69	6.014	2128.80	2004.65	135	-5.176	2128.04	2004.77
4	16.717	2129.76	2002.80	70	5.726	2129.10	2003.45	136	-5.263	2128.63	2006.47
5	16.649	2128.93	2003.04	71	5.639	2128.83	2004.65	137	-5.551	2128.93	2004.77
6	16.342	2128.93	2000.67	72	5.351	2128.93	2003.45	138	-5.638	2128.76	2006.47
7	16.273	2128.93	2003.04	73	5.264	2129.76	2004.65	139	-5.725	2128.93	2006.07
8	16.169	2128.30	2001.63	74	5.162	2128.74	2003.54	140	-6.013	2128.76	2006.47
9	15.9[illegible]	2128.93	2000.67	75	4.889	2128.76	2004.65	141	-6.100	2129.12	2006.07
10	15.899	2129.93	2003.04	76	4.793	2128.73	2003.54	142	-6.388	2129.47	2006.47
11	15.734	2128.83	2001.63	77	4.514	2129.62	2004.65	143	-6.475	2128.64	2006.07
12	15.523	2128.77	2003.04	78	4.418	2129.76	2003.54	144	-6.562	2129.06	2006.27
13	15.413	2128.94	2001.63	79	4.327	2128.80	2004.69	145	[illegible]	2128.93	2006.07
14	15.310	2129.18	2002.49	80	4.043	2128.76	2003.54	146	-6.937	2129.12	2006.27
15	15.044	2129.34	2001.63	81	3.952	2129.73	2004.69	147	-7.225	2128.77	2006.07
16	14.9[illegible]	2129.12	2002.49	82	3.663	2128.62	2003.54	148	-7.312	2129.10	2006.27
17	14.6[illegible]	2129.77	2001.63	83	3.577	2129.76	2004.69	149	-7.349	2129.06	2006.41
18	14.5[illegible]	2129.10	2002.49	84	3.490	2129.93	2002.39	150	-7.687	2129.10	2006.27
19	14.461	2129.18	2001.96	85	3.202	2128.67	2004.69	151	-7.774	2129.32	2006.41
20	14.1[illegible]	2129.19	2002.49	86	3.115	2129.32	2002.39	152	-8.062	2129.08	2006.27
21	14.0[illegible]	2129.22	2001.96	87	2.827	2126.78	2004.69	153	-8.149	2129.10	2006.41
22	13.[illegible]	2129.08	2002.49	88	2.740	2128.17	2002.39	154	-8.231	2129.06	2007.35
23	13.711	2129.19	2001.96	89	2.653	2125.44	2002.30	155	-8.524	2129.19	2006.41
24	13.606	2129.30	2002.80	90	2.365	2124.07	2002.39	156	-9.696	2129.32	2007.35
25	13.336	2129.19	2001.96	91	2.278	2122.74	2002.39	157	-8.890	2129.08	2006.41
26	13.231	2128.83	2002.80	92	1.990	2118.81	2002.39	158	-8.991	2129.10	2007.35
27	12.961	2129.08	2001.96	93	1.903	2111.37	2002.30	159	-9.068	2129.18	2006.77
28	12.856	2128.76	2002.80	94	1.816	2111.19	1997.95	160	-9.155	2129.13	2007.35
29	12.756	2128.68	2002.14	95	1.523	2103.59	2002.30	161	-9.443	2129.32	2006.77
30	12.481	2128.76	2002.80	96	1.441	2098.99	1997.95	162	-9.731	2129.08	2007.35
31	12.381	2128.73	2002.14	97	1.153	2093.25	2002.30	163	-9.818	2129.10	2006.77
32	12.106	2126.62	2002.80	98	1.066	2092.52	1997.95	164	-9.901	2128.93	2007.49
33	12.006	2128.76	2002.14	99	0.975	2080.08	1994.10	165	-10.193	2129.10	2006.77
34	11.[illegible]	2128.50	2003.31	100	0.691	2079.69	1997.95	166	-10.276	2129.12	2007.49
35	11.6[illegible]	2129.76	2002.14	101	0.600	2080.43	1994.10	167	-10.569	2129.08	2006.77
36	11.536	2128.93	2003.91	102	0.316	2099.07	1997.95	168	-10.651	2128.93	2007.49
37	11.256	2128.62	2002.14	103	0.225	2059.14	1994.18	169	-10.737	2129.31	2007.06
38	11.161	2128.93	2003.91	104	0.134	2098.71	1995.55	170	-11.026	2129.18	2007.49
39	11.065	2128.80	2001.91	105	-0.150	2105.81	1994.10	171	-11.103	2129.52	2007.06
40	10.796	2128.93	2003.91	106	-0.241	2113.61	1995.55	172	-11.401	2129.03	2007.49
41	10.6[illegible]	2129.83	2001.91	107	-0.525	2117.28	1994.10	173	-11.433	2129.44	2007.06
42	10.411	2128.77	2003.91	108	-0.616	2119.00	1995.56	174	-11.570	2129.25	2007.23
43	10.315	2128.76	2001.91	109	-0.703	2122.28	1999.75	175	-11.858	2129.44	2007.06
44	10.215	2128.74	2004.42	110	-0.991	2123.90	1995.55	176	-11.945	2129.32	2007.23
45	9.940	2128.76	2001.91	111	-1.078	2124.51	1999.75	177	-12.233	2129.39	2007.06
46	9.841	2128.83	2004.42	112	-1.366	2124.94	1995.56	178	-12.320	2129.27	2007.23
47	9.565	2128.77	2001.91	113	-1.453	2124.77	1999.75	179	-12.411	2129.56	2007.29
48	9.465	2128.76	2004.42	114	-1.540	2125.70	2002.94	180	-12.511	2128.99	2007.26
49	9.[illegible]	2128.87	2003.19	115	-1.828	2125.26	1999.75	181	-12.695	2129.27	2007.23
50	9.091	2128.84	2004.42	116	-1.915	2126.47	2002.84	182	-12.795	2129.71	2007.29
51	8.[illegible]	2128.93	2003.19	117	-2.203	2125.56	1999.75	183	-12.896	2129.12	2007.26
52	8.716	2128.62	2004.42	118	-2.290	2126.38	2002.94	184	-13.070	2129.39	2007.23
53	8.624	2128.84	2003.19	119	-2.391	2125.57	2004.59	185	-13.161	2129.61	2007.29
54	8.529	2129.44	2003.63	120	-2.655	2125.94	2002.84	186	-13.251	2129.01	2007.26
55	8.249	2128.93	2003.19	121	-2.756	2126.47	2004.59	187	-13.536	2129.61	2007.29
56	8.154	2129.52	2003.63	122	-3.040	2126.17	2002.94	188	-13.636	2129.10	2007.29
57	7.874	2128.68	2003.19	123	-3.131	2126.30	2004.59	189	-13.911	2129.54	2007.29
58	7.779	2129.61	2003.63	124	-3.214	2125.00	2005.43	190	-14.011	2129.00	2007.26
59	7.692	2129.13	2003.27	125	-3.506	2126.97	2004.59				
60	7.404	2129.31	2003.63	126	-3.599	2125.08	2005.43				
61	7.317	2129.22	2003.27	127	-3.881	2127.96	2004.59				
62	7.029	2129.33	2003.63	128	-3.9[illegible]4	2126.30	2005.43				
63	6.942	2129.18	2003.27	129	-4.051	2127.35	2004.77				
64	6.851	2128.99	2003.45	130	-4.139	2127.99	2005.43				
65	6.567	2129.19	2003.27	131	-4.426	2129.34	2004.77				
66	6.476	2129.12	2003.45	132	-4.714	2128.47	2005.43				

TABLE 2 - SUMMARY OF REDUCED DRAG COEFFICIENTS OF CIRCULATION CONTROL AIRFOIL MODEL 103

Run	M_∞	α (deg)	C_L	p_∞ (lb/ft^2)	T (F°)	q_∞ (lb/ft^2)	C_D Jones	C_D Squire-Young	C_D Simultaneous Solution
212	0.3	-0.01	0.0073	2002.82	97.05	126.11 127.00 128.00 126.35	0.0117 0.0238 0.0372	0.0151 0.0149 0.0147	0.0150
213	0.3	-0.01	0.0105	2001.81	94.62	126.00 127.06 128.00 127.20	0.0050 0.0196 0.0323	0.0219 0.0216 0.0213	0.0215
214	0.3	-0.01	0.0111	2000.75	93.66	127.00 128.18 129.00 128.23	0.0052 0.0211 0.0320	0.0221 0.0218 0.0216	0.0218
215	0.3	-0.01	0.0160	2001.38	92.58	127.00 128.00 129.00 127.86	0.0161 0.0298 0.0432	0.0281 0.0278 0.0274	0.0278
216	0.3	-0.01	0.0220	2002.95	92.27	125.00 126.00 127.00 126.07	0.0281 0.0415 0.0547	0.0430 0.0425 0.0419	0.0424
217	0.3	-0.01	0.0384	1999.30	90.27	129.00 130.34 132.00 130.64	0.0934 0.1106 0.1313	0.1167 0.1148 0.1124	0.1143
34	0.5	-5.99	0	1816.71	110.26	311.00 312.22 313.00 312.17	0.0055 0.0126 0.0170	0.0122 0.0121 0.0121	0.0121

					x/c	y/c	Cp
1	0.0000	0.0000	0.4166	35	0.8825	0.0605	-1.3418
2	0.0051	-0.0101	1.0428	36	0.8405	0.0677	-1.2210
3	0.0128	-0.0163	0.8645	37	0.7945	0.0750	-1.1276
4	0.0251	-0.0231	0.6615	38	0.7436	0.0806	-1.1032
5	0.0379	-0.0285	0.5422	39	0.6926	0.0843	-1.0243
6	0.0507	-0.0329	0.4390	40	0.6306	0.0871	-0.9649
7	0.0757	-0.0401	0.3268	41	0.5667	0.0890	-0.8965
8	0.1012	-0.0457	0.2525	42	0.5037	0.0891	-0.8882
9	0.1263	-0.0498	0.2020	43	0.4407	0.0877	-0.8407
10	0.1513	-0.0543	0.1614	44	0.3776	0.0843	-0.8437
11	0.1999	-0.0600	0.1344	45	0.3148	0.0803	-0.8179
12	0.2518	-0.0644	0.1071	46	0.2517	0.0733	-0.8193
13	0.3158	-0.0683	0.1064	47	0.2009	0.0672	-0.8058
14	0.3787	-0.0714	0.0985	48	0.1507	0.0588	-0.8161
15	0.4417	-0.0725	0.1015	49	0.1258	0.0547	-0.8244
16	0.5047	-0.0724	0.1242	50	0.1007	0.0486	-0.8444
17	0.5682	-0.0712	0.1419	51	0.0753	0.0421	-0.8699
18	0.6314	-0.0683	0.1842	52	0.0504	0.0343	-0.9215
19	0.6936	-0.0650	0.2419	53	0.0376	0.0296	-0.9863
20	0.7446	-0.0613	0.2956	54	0.0248	0.0239	-1.0260
21	0.7945	-0.0561	0.3673	55	0.0126	0.0168	-1.0826
22	0.8415	-0.0531	0.4350	56	0.0049	0.0103	-1.0071
23	0.8835	-0.0461	0.5689	57	0.0000	0.0000	0.4166
24	0.9165	-0.0402	0.5810				
25	0.9544	-0.0325	0.6197				
26	0.9784	-0.0239	0.6197				
27	0.9874	-0.0177	0.5885				
28	0.9989	-0.0016	0.5258				
29	0.9994	0.0000	0.2225				
30	1.0000	0.0049	-2.4728				
31	0.9934	0.0211	-4.8237				
32	0.9754	0.0316	-3.4785				
33	0.9494	0.0423	-1.6469				
34	0.9164	0.0525	-1.4780				

END

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